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Family Studies and Aetiology of Club Foot

RUTH WYNNE-DAVIES

From the Medical Research Council, Research Group on Genetic Problems in Orthopaedic Disease, Department of Orthopaedic Surgery, University of Edinburgh

Congenital club foot and talipes are used to describe various abnormalities of the foot in the newborn child. The most serious of these is talipes equinovarus in which there is plantar flexion of the ankle and inversion of the foot. This deformity is difficult to treat, having a marked tendency to recur, and causes a real disability. About half the cases are bilaterally affected. Patients frequently attend hospital for the first 10–15 years of life. A long-term follow up of the results of treatment of patients with talipes equinovarus has been reported elsewhere (Wynne-Davies, 1964a). The family findings in a series of patients with talipes equinovarus, mild (postural) talipes equinovarus, talipes calcaneo-valgus, and metatarsus varus have been reported in summary form (Wynne-Davies, 1964b). In this paper the family data, especially that on talipes equinovarus, are presented and discussed in more detail. Cases secondary to spina bifida, cerebral palsy, and arthrogryposis are not included.

Subjects and Method

The present study is based on patients attending the Princess Elizabeth Orthopaedic Hospital, Exeter, who were born in 1940-61.

This Orthopaedic Hospital serves the greater part of the largely rural county of Devon (excluding the Plymouth area), and there is available a stable population, making the tracing of families relatively easy. The orthopaedic service is based on the hospital at Exeter, and out-patient clinics are held at intervals of one, two, or four weeks throughout the county—at Exeter, Torquay, Newton Abbot, Okehampton, Barnstaple, Bideford, Honiton, and Tiverton. Patients attending currently for treatment during 1961 were seen at one of their routine visits to a clinic. Former patients were first approached by letter and were then seen at the outlying clinic which they had previously attended. A family history was taken from the individual, or where more appropriate, a parent, and nearly all affected relatives were personally examined. (Details of families with an affected first-degree relative are given in Appendix A.) In the only two instances where an affected first-degree relative was not seen personally, there was reliable medical evidence of the deformity (Index patients 30 and 108). Relatives stated to be normal were not specially examined, though in fact many were seen, as they attended with the patient. In the case of talipes equinovarus, with the standard of school and other medical services easily available in this country, it is most unlikely that such a severe deformity would pass unnoticed or ignored, and the ascertainment of affected relatives will be nearly complete. In the case of postural talipes equinovarus, talipes calcaneo-valgus, and metatarsus varus, relatives were not examined since these deformities almost invariably disappear and retrospective diagnosis is not possible. Only those cases confirmed by medical evidence have been classed as affected, but obviously many cases never reach hospital, and the ascertainment of affected relatives will be incomplete.

For talipes equinovarus, 163 case sheets were available for patients born from 1940 to 1961. Of these, 144 were traced of whom 133 were seen personally and 11 replied to questionnaires. Of the remaining 19, 13 were not traced, 2 were foster children, and 4 refused to co-operate. Index patients with the three other common forms of talipes were those born between 1948 and 1961; 31 patients were traced with postural equinovarus, 74 with talipes calcaneo-valgus, and 72 with metatarsus varus.

Results

Incidence. Since the Princess Elizabeth Orthopaedic Hospital is the only orthopaedic hospital in the area and both private and National Health Service patients have been included, ascertainment of cases needing hospital treatment will be nearly complete. Comparing the numbers of patients with the Registrar General's figures for all live births in the area over the same period, the incidences of the different forms of the malformation were: talipes equinovarus—1·24 per 1000 live births (males 1·62 per 1000, females 0·80); postural talipes equinovarus—0·50 per 1000 live births (males 0·24 per 1000, females 0·78); talipes calcaneo-valgus—1·09 per 1000 live births (males 0·07 per 1000, females 0·33); meta-

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tarsus varus—1·21 per 1000 live births (males 1·02 per 1000, females 0·19).

The total incidence, 4·04 per 1000 live births, is very similar to McKeown and Record's (1960) finding of 4 per 1000 total births in their Birmingham survey, but in their survey the types were not differentiated. The figure for the most serious malformation, talipes equinovarus, 1·24 per 1000 live births, is very similar to that recorded from Sweden of 1 per 1000 live births (Hilsonner, 1927, cited by Böök, 1948).

Associated Malformations. The malformations associated with club foot have been presented in detail elsewhere (Wynne-Davies 1964b). They fall into two groups.

(a) Minor defects of connective tissue in patients with talipes equinovarus and calcaneo-valgus, such as generalized joint laxity (present in over 10% of patients with talipes equinovarus and talipes calcaneo-valgus) and inguinal hernia (present in 7% of boys with talipes equinovarus and talipes calcaneo-valgus).

(b) Minor deformities of the extremities such as syndactyly, polydactyly, oligodactyly, and ring constrictions of fingers (present in 4·5% of patients with talipes equinovarus, talipes calcaneo-valgus, and metatarsus varus). Patients with talipes calcaneo-valgus show the recognized association of this malformation with congenital dislocation of the hip (5%).

Sex Ratio. 97 of the 144 patients with talipes equinovarus were male, giving a sex ratio of 2·1. Most authors have also reported a sex incidence of about 2. In contrast, 35 of the 46 patients with postural talipes equinovarus were girls, giving a sex ratio of 0·31. Of the 100 patients with talipes calcaneo-valgus, 60 were girls, giving a sex ratio of 0·66. Of the 111 patients with metatarsus varus, 62 were girls, giving a sex ratio of 0·79.

Maternal Age and Birth Order Effects. No parental age or birth order effect was found for talipes equinovarus. The analysis of the 94 cases of talipes equinovarus born between 1948 and 1960 is shown in Table I. The mean maternal age was 26·0 years and the mean paternal age 28·8 years. Similarly, no parental age or birth order effects were found for postural talipes equinovarus or with metatarsus varus (Wynne-Davies, 1964b). In contrast, with talipes calcaneo-valgus there was a highly significant excess of first-born children in comparison with the general population. This is shown in Table II. There was also an excess of children born to younger mothers, but this is probably coincidental to the birth order effect.

TABLE I

TALIPES EQUINOVARUS

BIRTH ORDER AND MATERNAL AGE—COMPARED WITH NATIONAL FIGURES FOR ENGLAND AND WALES: DEVON BIRTHS 1948–1960

Maternal Age	15–24	25–29	30–34	35+	Total
Index cases	29	33	22	10	94
General population	31·54	30·64	19·01	12·82	

$\chi^2_{(3)} = 1{\cdot}48$; $p > 0{\cdot}10$. Not significant

Previous Children	0	1	2	3+	Total
Index cases	45	23	17	9	94
General population	37·19	28·75	14·28	13·78	

$\chi^2_{(3)} = 4{\cdot}97$; $p > 0{\cdot}10$. Not significant.

TABLE II

TALIPES CALCANEO-VALGUS

BIRTH ORDER AND MATERNAL AGE—COMPARISON WITH NATIONAL FIGURES FOR ENGLAND AND WALES: DEVON BIRTHS 1948–1960

Maternal Age	15–24	25–29	30–34	35+
Index cases	32	13	10	8
General population	21·14	20·53	12·74	8·59

$\chi^2_{(3)} = 8{\cdot}97$; $0{\cdot}05 > p > 0{\cdot}025$

Previous Children	0	1	2	3
Index cases	39	8	5	11
General population	24·92	19·27	9·57	9·24

$\chi^2_{(3)} = 17{\cdot}06$; $p < 0{\cdot}001$.

Parental Consanguinity. In no instance in the whole series of 347 cases was there parental consanguinity.

Findings in Relatives.

Twins. One boy and one girl index patient with talipes equinovarus had monozygotic co-twins who were unaffected (the male twins were concordant for blood groups A, CDE/cde, MN, K−, P+, Fy^a; the female twins were not grouped). One boy with talipes equinovarus had a dizygotic twin brother (differing in Rhesus group) who was also an index patient with postural talipes equinovarus. One girl index patient with talipes calcaneo-

valgus had an unaffected dizygotic twin sister (differing in Kell types). A girl index patient with metatarsus varus had a probable monozygotic twin sister (not grouped) who was unaffected.

These twins have been included among the sibs in the following section.

First-degree Relatives. The findings on the parents and brothers and sisters of the talipes equinovarus patients are shown in Table III and those of the other three groups in Appendix B.

TABLE III

TALIPES EQUINOVARUS, 1940–61 GROUP: FIRST-DEGREE RELATIVES

	Father	Mother	Brothers	Sisters
Male index 97	97 (1)	97 —	115 (4) (1 MV)	90 — (1 MV)
Female index 47	47 (3)	47 — (1 CV)	33 (2)	34 (2) (1 MV)
Total 144	144 (4)	144 — (1 CV)	148 (6) (1 MV)	124 (2) (2 MV)

Those with the same deformity shown in brackets; calcaneo-valgus (CV) and metatarsus varus (MV) are also shown.

For all index patients with talipes equinovarus the over-all proportion of first-degree relatives affected with the same malformation was 12 in 560, 2·14%. For male index patients, 1 of 97 fathers, 4 of 115 brothers, but no mother, and none of 90 sisters were affected. For female index patients, 3 of 47 fathers, 2 of 33 brothers, no mother, but 2 of 34 sisters were affected. Thus, for male index patients 5 of 212 (2·3%) of male and 0 of 187 female first-degree relatives were affected. For female index patients, 5 of 80 (6·2%) of male and 2 of 81 (2·5%) of female first-degree relatives were affected. If relatives of both sexes are combined, the higher proportion of affected relatives of female index patients is significant at the 5% level. The index patients were too young to have children but in a further series of patients born before 1940, 35 male index patients had 0 of 16 sons and 1 of 13 daughters similarly affected; and 12 female index patients had 0 of 8 sons and 0 of 5 daughters similarly affected. In addition, 1 relative had calcaneo-valgus and 3 had metatarsus varus.

In the small number, 113, of first-degree relatives of patients with postural talipes equinovarus, 3 (2·65%) were similarly affected, but in addition it is interesting that 1 relative had talipes equinovarus and 2 had talipes calcaneo-valgus.

Of the 258 first-degree relatives of patients with talipes calcaneo-valgus, 8 (3·10%) were similarly affected. Of 263 first-degree relatives of patients with metatarsus varus, 5 (1·81%) had a similar malformation, and in one of these the metatarsus deformity was combined with equinovarus. In addition, 3 of the relatives had talipes equinovarus.

Second- and Third-degree Relatives. The findings on aunts and uncles and on first cousins of talipes equinovarus index patients are set out in Table IV.

The over-all proportion of aunts and uncles with the same malformation is 5 in 823 (0·61%) and of first cousins, 2 in 991 (0·20%).

Malformations Other Than Those of Central Nervous System. The incidence of other malformations in relatives appears to be no more than the random incidence, except that patients with talipes equinovarus and talipes calcaneo-valgus had relatives affected by other conditions that are associated with generalized joint laxity (Carter and Sweetnam, 1960; Carter and Wilkinson, 1964); two mothers of talipes equinovarus patients

TABLE IV

TALIPES EQUINOVARUS: SECOND AND THIRD DEGREE RELATIVES

	Uncles and Aunts				Paternal Cousins		Maternal Cousins	
	Father's		Mother's		Male	Female	Male	Female
	Brothers	Sisters	Brothers	Sisters				
1940–61 group								
Male	143	130	143	152 (2)	172	181	169 (2)	168
Female	80 (1)	53	58	64 (2)	73	70	93	66
Total	223 (1)	183	201	216 (4)	245	250	262 (2)	234

Those with the same deformity shown in brackets.

had congenital dislocation of the hip; one mother of a talipes calcaneo-valgus patient (who also had recurrent dislocation of the patella) had congenital dislocation of the radial heads; a brother of another patient had congenital dislocation of the hip; and a sister of yet another patient had recurrent subluxation of the shoulders.

Discussion

The admirable twin study by Idelberger (1939) showed that both genetic and environmental factors were concerned in the development of talipes equinovarus. He found that there were 13 of 40 monozygotic twins (32·5%) of patients, and 4 of 134 dizygotic co-twins (2·9%) also affected.

This study shows a substantial familial concentration for patients with talipes equinovarus, and confirms the evidence from twins that genetic factors are important in the aetiology of the condition. Over-all incidence in parents and sibs of patients with talipes equinovarus, of 12 in 560, or 2·14% (± 0·62), is about 17 times the population incidence of 0·124%. The over-all incidence in aunts and uncles of 5 in 823, or 0·61%, is about 6 times the population incidence, and that in cousins, 2 in 991, is very close to the population incidence.

These relative incidences would be compatible with the hypothesis of genetic predisposition to talipes equinovarus by a dominant gene with a low rate of manifestation. It is, however, much more likely that the genetic predisposition is multifactorial. One element in this predisposition is probably a genetically determined generalized joint laxity, which was found in a substantial proportion of patients and often behaves as if due to a dominant mutant gene (Carter and Sweetnam, 1958), and also predisposes to such abnormalities as congenital dislocation of the hip, recurrent dislocation of the shoulder, and dislocation of the radial heads, which in this series were found in the first-degree relatives of index patients.

The family findings in the other three conditions are also probably best explained in terms of multifactorial genetic predisposition with an important environmental component. The increase observed in the incidence in first-degree relatives compared to that in the general population is about thirtyfold for talipes calcaneo-valgus, fiftyfold for postural equinovarus, and about fifteenfold for talipes metatarsus varus.

The family findings suggest a relationship of talipes equinovarus with metatarsus varus, but much less clearly with calcaneo-valgus; the mild postural talipes equinovarus appears to have links with calcaneo-valgus. Familial generalized joint laxity could be the link between talipes equinovarus and calcaneo-valgus, and a mild connective tissue abnormality could account for the association of both these conditions with joint laxity and inguinal hernia. Some other mechanism must be involved for the relationship between equinovarus and metatarsus varus, since in the latter there is no association with joint laxity or with inguinal hernia.

There are no indications yet of the environmental factors involved, but intrauterine posture is likely to be important. The intrauterine posture, which Wilkinson (Wilkinson, 1963) has suggested is important for congenital dislocation of the hip, namely flexed hips, extended knees, and externally rotated feet, may predispose to calcaneo-valgus as well and accounts for the association between the two conditions, and it is noteworthy that there is an excess of first-born in both congenital dislocation of the hip and calcaneo-valgus.

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APPENDIX A

Details of Families in which a First-degree Relative is Affected with One of the Forms of Talipes, Calcaneo-valgus, and Metatarsus Varus

Index patients are in italics; similarly affected sibs are marked with an asterisk; s.b. is stillborn; d. is died; twins are in square brackets; TEV is talipes equinovarus; PTEV is postural talipes equinovarus; MV is metatarsus varus; CV is calcaneo-valgus; B. is bilateral; L. is left; R. is right.

Case No.	Sibship	Date of Birth	
		Mother	Father
Talipes Equinovarus			
15 (335 and 302)	F (B.MV) 5·49; M 8·50; *M* (B.TEV) 8·51; M 9·55 [M (B.MV) 4·57; F 4·57]	5·28	4·29
30	M 1·48; *M* (L.TEV) 8·49; M 10·50; F 3·52 M* (B.TEV) 7·53; M 8·55	10·28	11·27
32 and 158	M 7·33; M 4·35; *M* (R.TEV) 11·36; M 8·38; *M* (R.TEV) 4·40	3·09	1·03
53 (and 196)	F 6·52; F 4·54; [*M* (B.TEV) 5·61; M (B.PTEV) 5·61]	8·27	1·25
55	F 10·39; *M* (R.TEV) 12·58	9·17	12·14 (R.TEV)
75 and 76	*M* (R.TEV) 10·40; *M* (R.TEV) 8·42; M 11·51	1·19	10·06
108	F 3·35; *F* (R.TEV) 5·45	9·10	5·10 (B.TEV)
111 and 112	F 2·39; *F* (R.TEV) 8·45; *F* (R.TEV) 8·46	2·25	5·22
118	*F* (B.TEV) 12·55; F 12·56; M 6·59	5·32 (B.CV)	3·30
135	M* (B.TEV) 7·38· *F* (B.TEV) 2·40· F 10·42; F 5·51	5·14	10·08 (B.TEV)
141	*F* (R.TEV) 3·61	1·33	9·33 (R.TEV)
143 (and 368)	*F* (R.TEV, L.MV) 5·50 [M*d. (B.TEV) 10·52; M 10·52] F 6·54; F (R.MV) 10·56; M 7·60	5·24	1·14
Postural Talipes Equinovarus			
194	M* (B.PTEV) 12·57; *M* (B.PTEV) 6·60	5·36	8·35
196	(See TEV No. 53)		
199	M 3·48; M 4·49; *F* (B.PTEV) 3·52	11·25	2·23 (B.CV)
205	*F* (B.PTEV) 3·57; F 10·60	4·38 (B.CV)	3·31
208	F 1·50; *F* (B.PTEV) 9·52; M 8·54; M* (B.PTEV) 2·56	11·30	12·28
222	M 9·44; F* (L.PTEV) 8·46; *F* (R.PTEV) 9·50	7·24	11·11
Calcaneo-valgus			
225 and 251	*M* (B.CV) 10·55; *F* (B.CV) 1·60	6·27	5·23
237	*M* (B.CV) 12·57; M* (B.CV) 3·60	7·36	11·33
285	M* (B.CV) 7·59; *F* (R.CV) 8·60	6·39	3·38
293 and 294	*F* (B.CV) 7·54; F 1·57; *F* (B.CV) 7.58	4·27 (R.CV)	1·29
Metatarsus Varus			
302 and 335	See TEV No. 15		
316	M 3·48; *M* (B.MV) 6·49; *F* (B.MV) 5·53	8·26	11·23
368	See TEV No. 143		

Appendix B overleaf

APPENDIX B

Findings in First-degree Relatives of Patients with Postural Talipes Equinovarus, Talipes Calcaneo-valgus, and Metatarsus Varus

	Fathers	Mothers	Brothers	Sisters
(A) *Postural Talipes Equinovarus**				
Male				
index 7	7	7	5 (1) (1 TEV)	5
Female				
index 24	24 (1 CV)	24 (1 CV)	25 (1)	16 (1)
Total 31	31 (1 CV)	31 (1 CV)	30 (2) (1 TEV)	21 (1)
(B) *Talipes Calcaneo-valgus**				
Male				
index 26	26	26	24 (1)	14 (1)
Female				
index 48	48	48 (2)	33 (2)	39 (2)
Total 74	74	74 (2)	57 (3)	53 (3)
(C) *Metatarsus Varus**				
Male				
index 30	30	30	26 (1 TEV)	25 (2)
Female				
index 42	42	42	38 (2) (2 TEV)	30 (1 MV/TEV)
Total 72	72	72	64 (2) (3 TEV)	55 (3) (one of these MV/TEV)

* First-degree relatives with same deformity are shown in parentheses.

In (A) talipes equinovarus and calcaneo-valgus deformities are also shown. In (C) talipes equinovarus deformities are also shown.